SO_3 and Sulfate levels observed and Operational Issues Co-firing Coal and Biomass blends under Oxy-firing conditions

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Oxy-combustor facility

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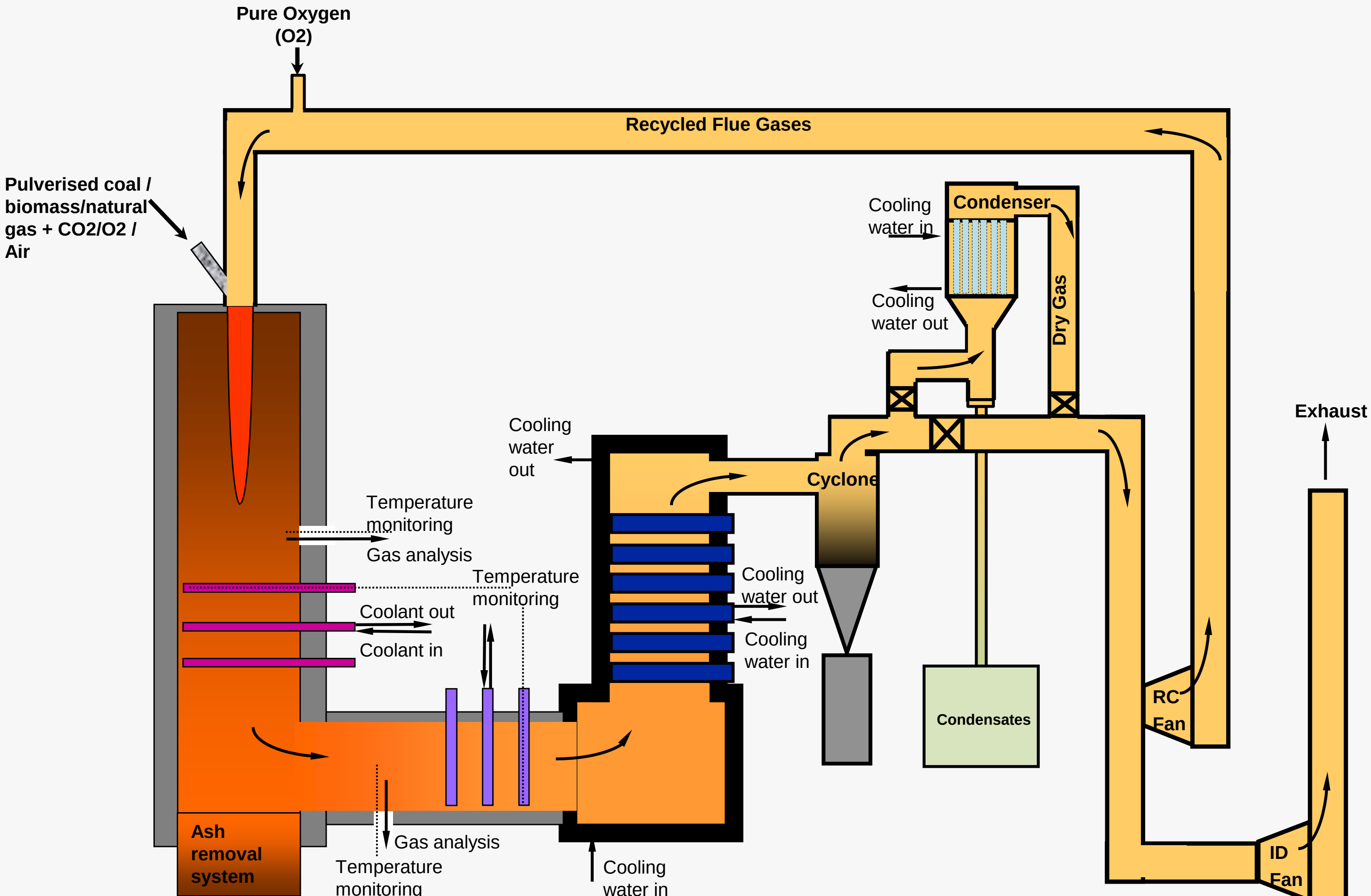

Diagram of 100kW$_{th}$ Oxy-Combustor with Condenser

Oxy-combustor facility

FLUE GAS CONDITIONING

CONDENSER

New calibration model needed for the FTIR (Higher concentrations of CO_2 expected)

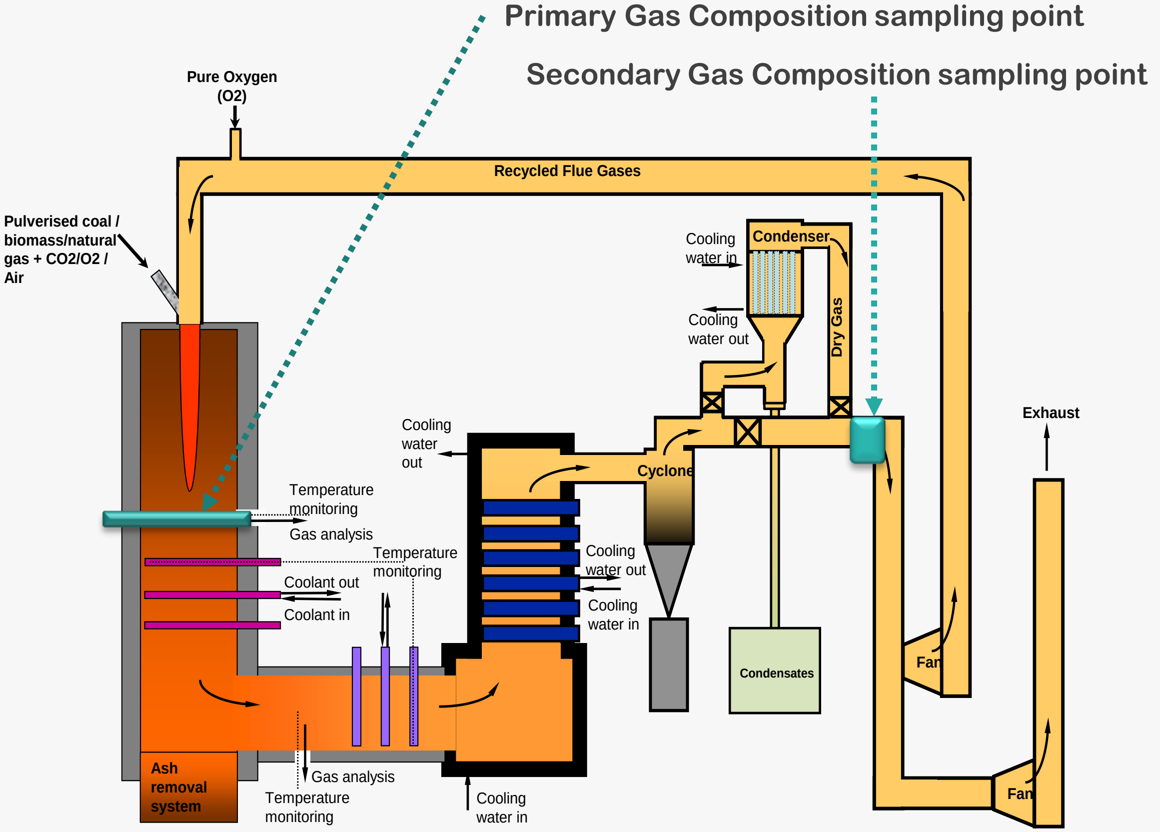

Diagram of 100kWth Oxy-Combustor with Condenser

Oxy-combustor facility
NEW MEASUREMENTS

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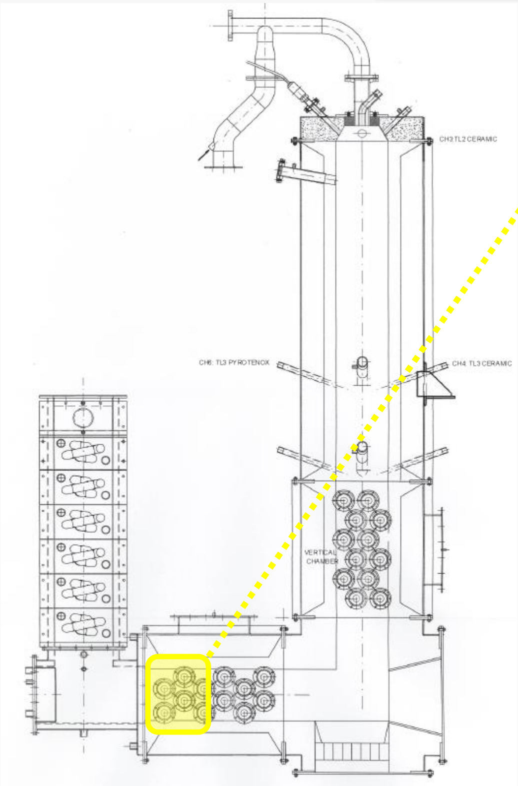
SO_3 AND SULFATES MEASUREMENT
(Controlled Condensation Method)



Location of the sampling point

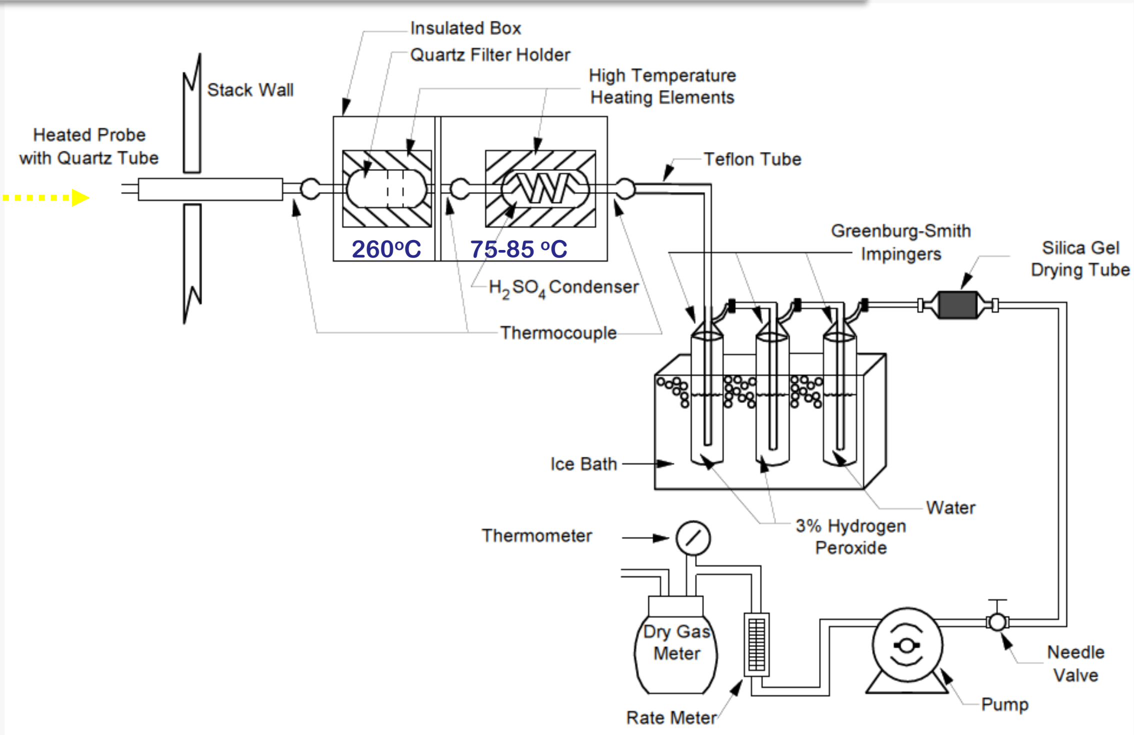


Diagram for SOx sampling train proposed in EPA Method 8A

Modification of procedure suggested by EPA Method 8A applied

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Oxy-combustor facility
NEW MEASUREMENTS

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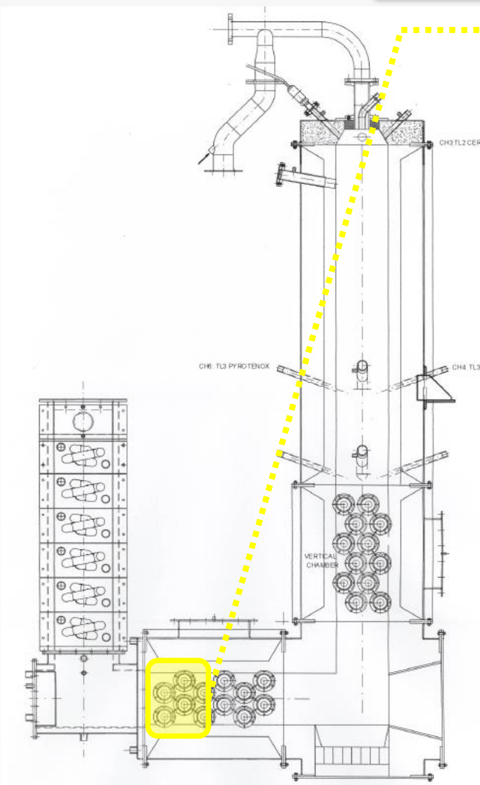

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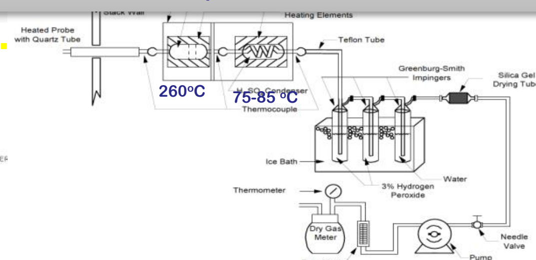
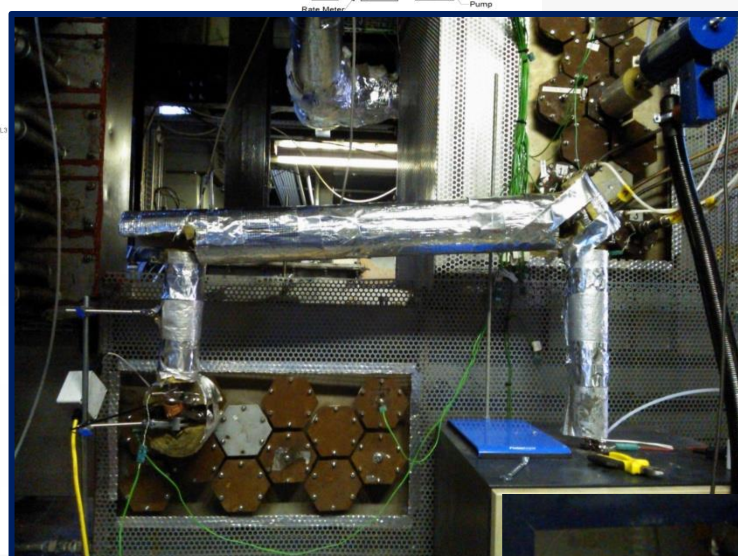
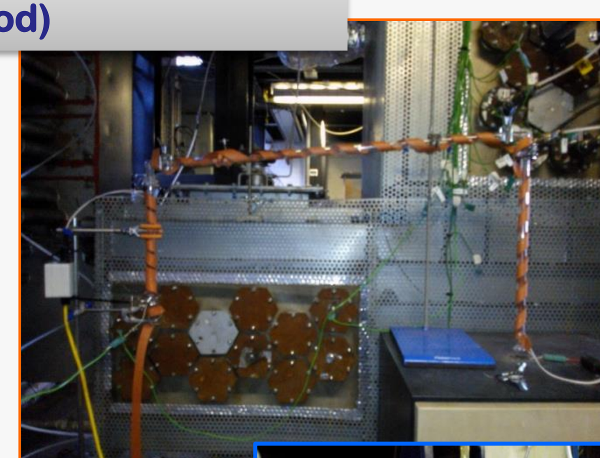


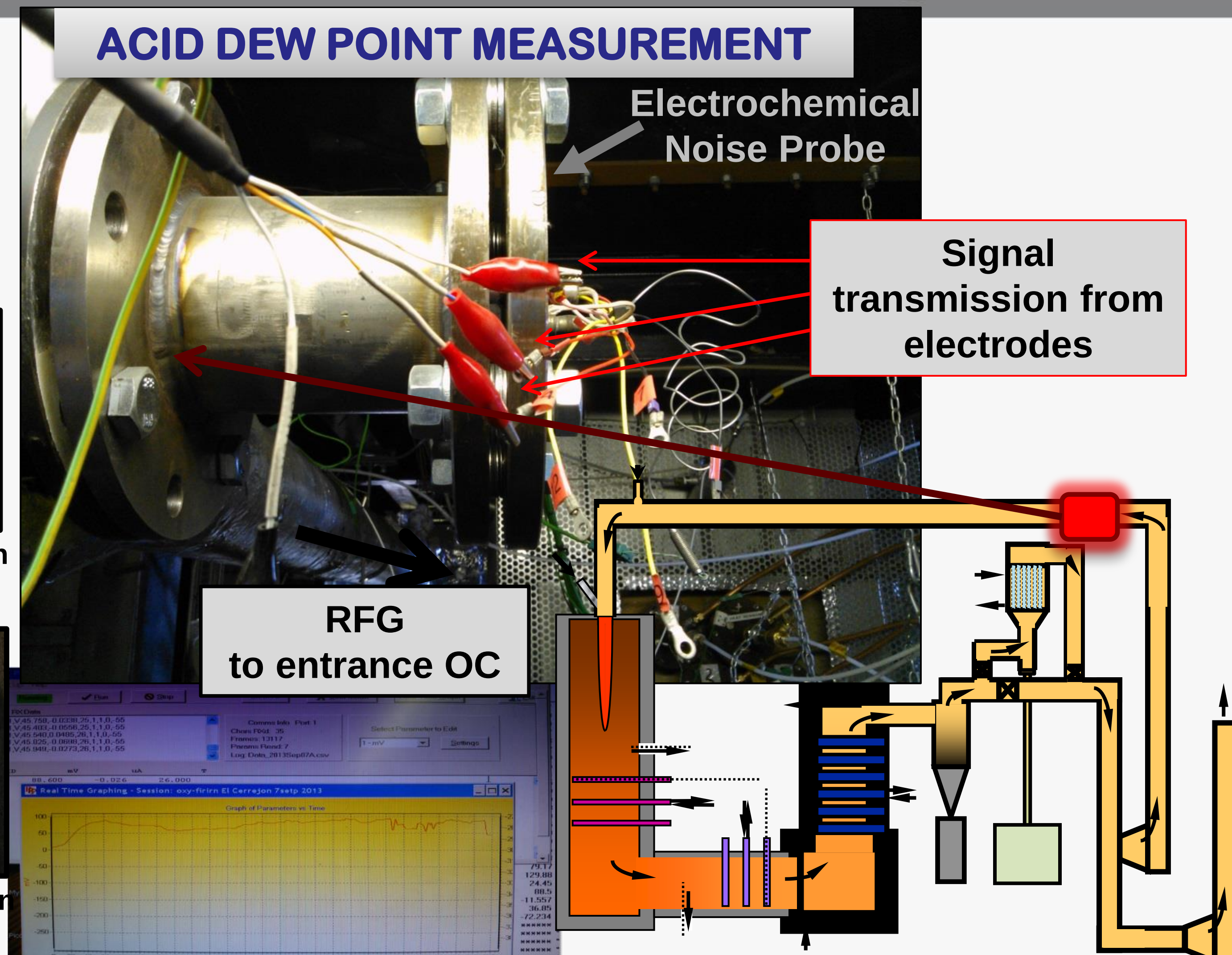




Oxy-combustor facility

NEW MEASUREMENTS

RFG
from RC Fan



Electrodes section before a test

Electrodes section after a test

Experimental conditions

- Type of fuel: El Cerrejon Coal 13.5kg/h
  75% El Cerrejon -25% CCP 15kg/h
  50% El Cerrejon -50% CCP 16.7kg/h
  Cereal co –product 22kg/h
- Percentage of Recycled Flue Gas :60-65%
- Types of Recycled Flue Gas
  - Wet- Hot Recirculation (After Particle Removal)
  - Dry – Cool Recirculation (After Particle, Condenser)
- Oxygen Injection
  - Primary O_2 (Fuel carrier draught): Not Used
  - Secondary O_2: 34-38% in gas supplied

Experimental conditions

FUEL ANALYSIS

	El Cerrejon coal	Cereal co-product
Proximate analysis (% (wt) as received)		
Moisture	5.80	8.10
Volatile matter	34.80	70.80
Ash	8.60	4.20
Calorific value, (MJ/kg)		
Gross calorific value	27.85	17.61
Net calorific value	27.12	16.34
Ultimate analysis (% (wt) as received)		
Carbon	69.2	43.30
Hydrogen	4.40	5.80
Nitrogen	1.42	2.70
Chlorine	0.02	0.17
Sulfur	0.58	0.16
Oxygen	9.98	35.57
Ash analysis (% (wt))		
SiO_2	60.69	44.36
Al_2O_3	22.01	2.79
Fe_2O_3	7.43	2.47
TiO_2	0.92	0.12
CaO	2.27	7.78
MgO	2.90	3.96
Na_2O	1.06	0.36
K_2O	2.32	24.72
Mn_3O_4	0.06	0.10
P_2O_5	0.21	12.04
SO_3	-	-
BaO	0.11	0.05

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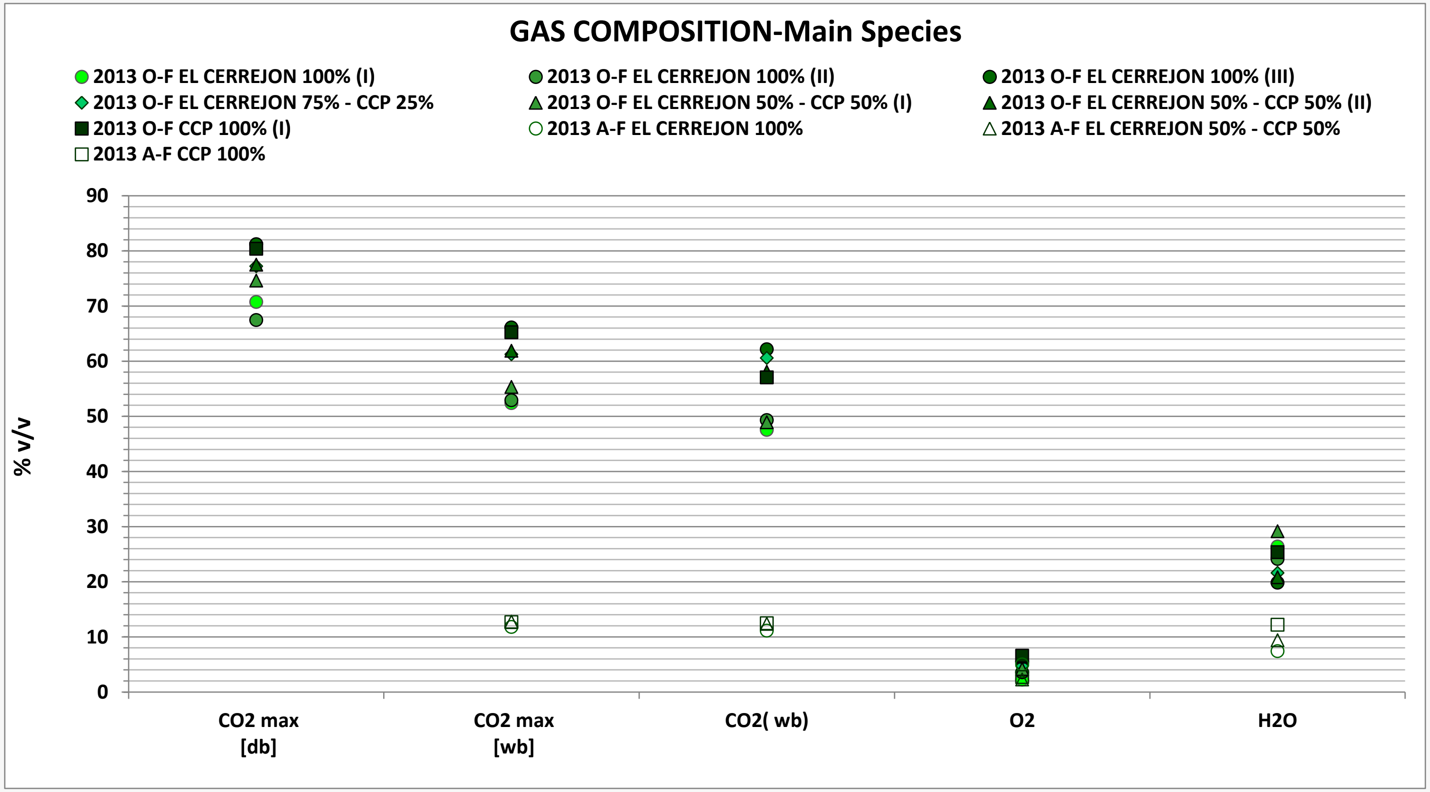
Experimental Results
GAS COMPOSITION

- **Maximum CO_2 : 57-62% wet basis [80-81% (d. b.)]**
- **H_2O ~ 20-29% (v/v)**
- **O_2~ 4.3% (v/v)**



Experimental Results

GAS COMPOSITION

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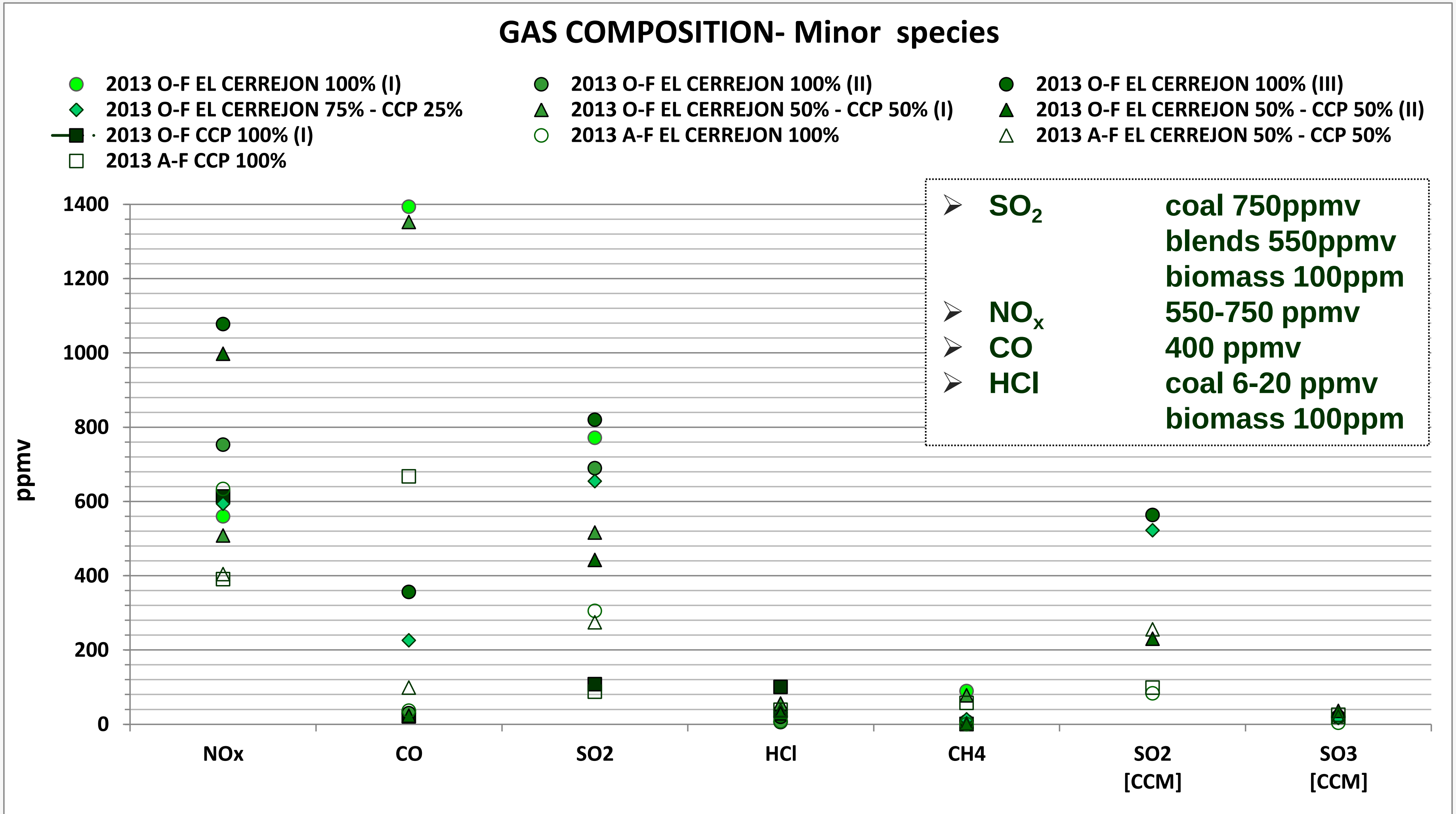

- SO_2 coal 750ppmv
  blends 550ppmv
  biomass 100ppm
- NO_x 550-750 ppmv
- CO 400 ppmv
- HCl coal 6-20 ppmv
  biomass 100ppm

Experimental Results

SO3 & SULFATES

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	SO_2_FTIR (ppmv)	SO_2_CCM (ppmv)	$(SO_3+SO_4^{2-})$_CCM (ppmv)	$(SO_3+SO_4^{2-})/SO_2$ (%)
Air-firing El Cerrejon	305.2	83.5	3.0	3.6
Air-firing 50%EC-50%CCP	274.3	245.8	16.6	6.7
Air-firing CCP	87.6	98.9	20.8	21.0
Oxy-firing El Cerrejon	819.6	566.8	16.9	3.0
Oxy-firing 75%EC-25%CCP	654.3	525.2	13.8	2.6
Oxy-firing 50%EC-50%CCP	442.2	231.4	29.5	12.7

Effect of fuel: $SO_3+SO_4^{2-}$ levels rising as the share of CCP increases

- Alkalis reaction with SO_3 to generate sulfates
- SO_2 to SO_3 promoted by alkalis

Effect of firing mode: $SO_3+SO_4^{2-}$ levels in oxy-firing higher than in air-firing

Experimental Results
ACID DEW POINT

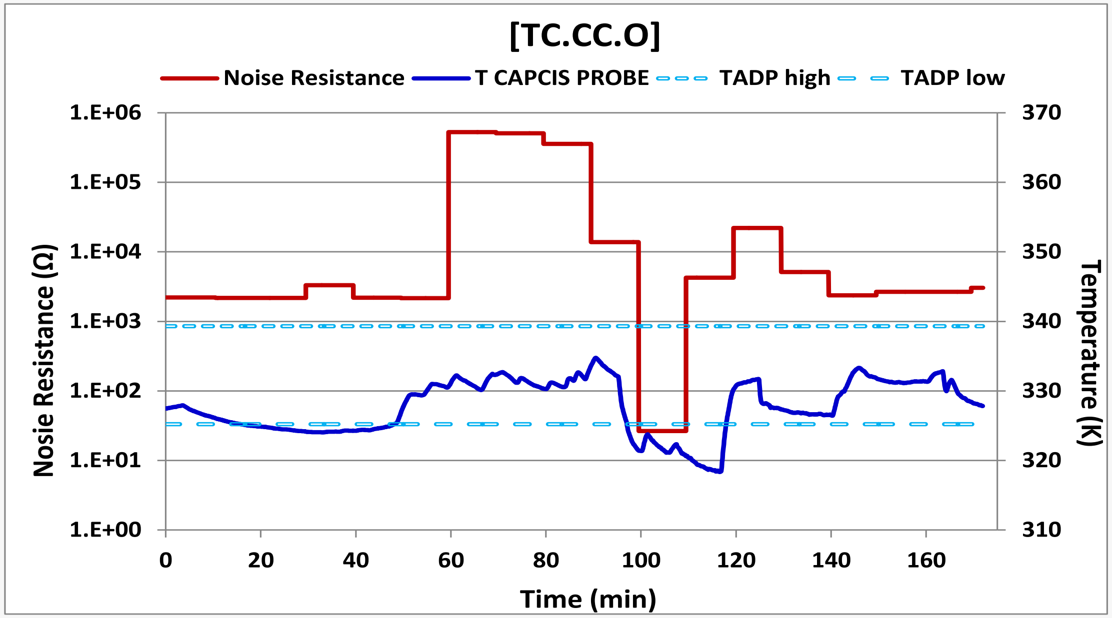
Ohm's Law:

$$R(\Omega) = \frac{V(V)}{I(A)}$$

$$NR(\Omega) = \frac{std(V)}{std(I)}$$

<u>*Explanation:*</u>

$$\uparrow I \rightarrow \uparrow \left(\frac{\partial I}{\partial t}\right) \rightarrow \uparrow Reaction\ rate_{Corrosion}\ \&\ \downarrow NR$$



Empirical acid dew points are lower than the estimated values for the high T_{ADP}

Theoretical correlations result in conservative estimations for the acid dew points

Experimental Results

HEAT FLUX

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	Heat flux$_{Max}$ (kW/m^2)	Heat flux$_{Av}$ (kW/m^2)	RFG (%)	Power$_{supplied}$ (kW)
Air-firing El Cerrejon	42.9	35.8	-	108
Air-firing 50%EC-50%CCP	33.7	29.2	-	108
Air-firing CCP	85.5	31.4	-	101
Oxy-firing El Cerrejon	191.7	153.8	60	119
Oxy-firing 75%EC-25%CCP	38.8	33.6	67	105
Oxy-firing 50%EC-50%CCP	82.7	63.8	60	105
Oxy-firing CCP	150.6	109.9	54	118

- Heat fluxes generated in oxy-firing double the air-firing cases
- El Cerrejon coal leads to heat fluxes 1.25 times higher than 100% CCP

Experimental Results

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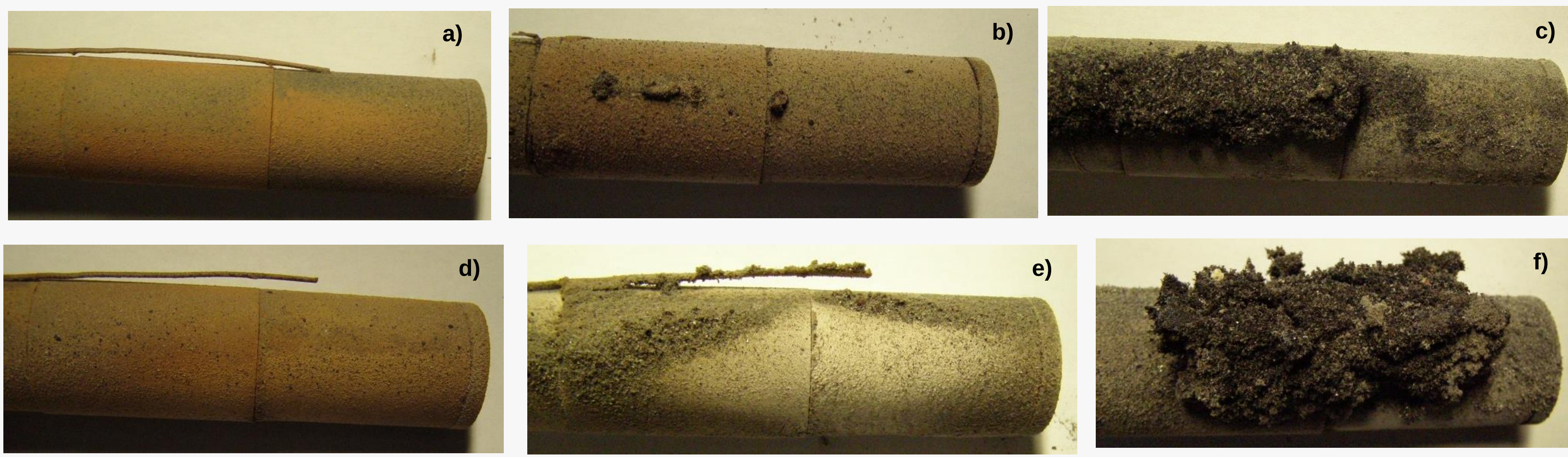
Experimental Results

ASH DEPOSITS

The structure of the deposit is more fibrous and porous using 100% CCP than when oxy-firing 100% El Cerrejon coal or the coal-biomass blends. No significant difference in the aspect of the deposits can be observed comparing the cases under oxy and air-firing conditions.



a) Air- firing El Cerrejon b) Air-firing 50%EC-50%CCP c) Air-firing CCP
d) Oxy- firing El Cerrejon e) Oxy-firing 50%EC-50%CCP f) Oxy-firing CCP

Experimental Results
ASH DEPOSITS

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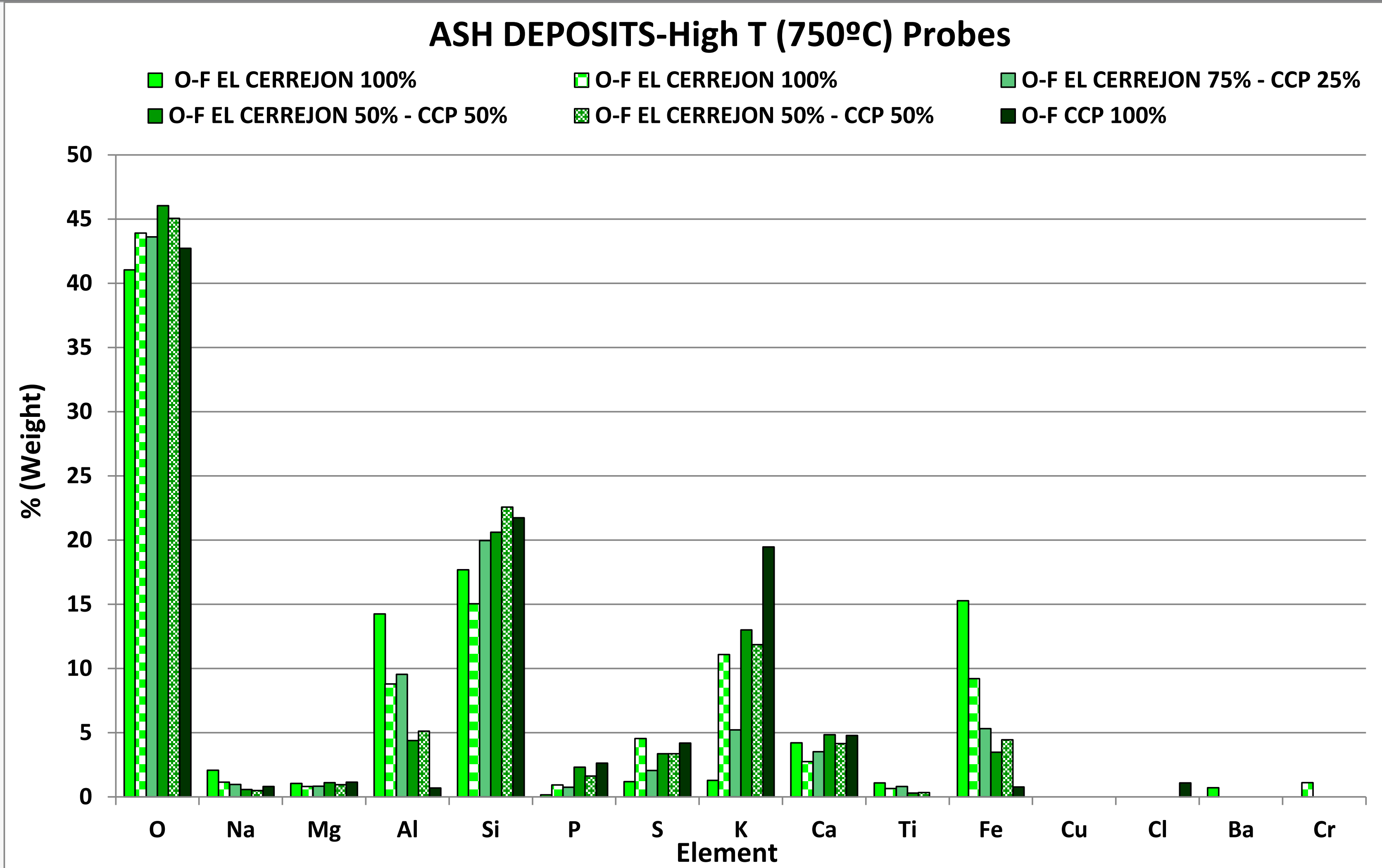

Operational issues

- Decrease of air ingress from 10% to 5% (improved sealing of the facility and operation at slightly positive pressure)
- Difficulty to control the %RFG when using coal-biomass blends and pure biomass (liquid accumulation in the condenser)
- The $\eta_{condenser}$ dropped sharply after two hours of operation
- Dry recycle used from the start of the tests with 100% biomass (otherwise minimal efficacy)
- Some air ingress into the process through the deposit probes (due to cooling air)
- Appropriate maintenance of heat flux sensor

Key findings- Experimental

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- Gas composition
  - CO_2 — >80% (db) for pure coal and pure biomass
  - H_2O — 20-29%, even with dry recycle
  - NO_x — 550-750ppmv
  - SO_2 — 100-750ppmv
  - HCl — 8-100ppmv
  - $SO_3+SO_4^{2-}$ — 14-30ppmv

  Clear increase in $(SO_3+SO_4^{2-})/SO_2$ ratio when ↑%CCP
- Acid dew point
  - Theoretical correlations result in conservative estimations for the acid dew points
- Heat flux
  - oxy-firing double the air-firing cases
  - Coal leads to heat fluxes 1.25 times higher than 100% CCP

  Not possible compensation for heat flux
- Ash deposits
  - Markedly fibrous and cohesive for high shares of CCP
  - Similar S levels for pure coal and biomass (K_2SO_4 generation)

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Thanks for your attention

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